UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES--SERVICE SPILLWAY--ALAMOGORDO DAM ENLARGEMENT

Hydraulic Laboratory Report No. Hyd-416

DIVISION OF ENGINEERING LABORATORIES

COMMISSIONER'S OFFICE
DENVER, COLORADO

December 14, 1956

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Division of Engineering Laboratories
Hydraulic Laboratory Branch
Denver, Colorado
December 14, 1956

Laboratory Report No. Hyd-416
Compiled by: D. Colgate
Checked and
reviewed by: J. W. Ball
Submitted by: H. M. Martin

Subject: Hydraulic model studies--Service spillway--Alamogordo Dam Enlargement

PURPOSE OF THE STUDY

The purpose of this model study was to (a) insure that the radial gates as initially installed would continue to operate satisfactorily for reservoir elevations up to 4275.0 where they are automatically drawn up out of the stream, (b) determine the portions of the spillway and crest which could be retained without change, and (c) calibrate and test for proper hydraulic operation of the new control structure for the service spillway.

CONCLUSIONS

1. The nine 16-foot-high rectangular openings between the buttresses as shown on Figure 11 will pass the design flood of 56,000 cfs when the reservoir water surface elevation is 4297.0.

2. The existing radial gates will operate satisfactorily for control for any reservoir water surface up to elevation 4275.0.

3. No adverse pressure conditions will be encountered on the existing spillway surface downstream from the gate seat, Station 2+92.67. This portion of the spillway may be retained without shape change.

4. Unsatisfactory operation would result if the gates were used to regulate the flow and the reservoir water surface contacted the bottom of the curtain wall or hood. Such a condition would cause the control to shift back and forth between the gate and the wall setting up a violent surging that would endanger the structure.

5. There will be a marked reduction in the tendency to scour the spoil bank which extends into the reservoir from the left approach to the spillway. Before modification, this bank was subjected to velocities of about 10 fps for a reservoir elevation of 4275.2; with the recommended

control structure, the velocities here for the same reservoir elevation would be about 6 fps (Figure 15A and B).

6. An underdrain outlet hood placed on the spillway face in line with the center of one of the rectangular control orifices, and with its downstream face at Station 3+10.0, would take advantage of the greatest reduction in pressure at the underdrain outlet (Figures 17 and 18).

RECOMMENDATIONS

It is recommended that the present operating procedure of controlling the flow with the radial gates only when the reservoir is at or below elevation 4275.0 be continued. Unsatisfactory hydraulic operation, a violent surging between the gate and the curtain wall, would result if the gates were permitted to control with the reservoir above this elevation.

INTRODUCTION

Alamogordo Dam on the Pecos River in New Mexico (Figure 1) is a rolled earth structure 149 feet high, 1,600 feet long at the crest, and 1,150 feet thick at the riverbed. The dam was completed in December 1937. The reservoir has the dual purpose of flood control and to provide storage to supplement the Avalon and McMillen Reservoirs for irrigation of lands in the Carlsbad Project. The reservoir capacity was 157,000 acre-feet at normal reservoir water surface, elevation 4275.0. The spillway was designed to pass 56,000 cfs at reservoir elevation 4279.7 (maximum water surface) where the storage capacity was 180,000 acre-feet. Three radial gates controlled the water surface up to reservoir elevation 4275.0 (Figure 2). When the reservoir exceeds elevation 4275.0, the gates automatically raise out of the flow.

The recent plans for the enlargement of Alamogordo Dam included a gate structure headwall across the spillway at the upstream end of the piers, and additional earth embankment, which would allow an increased reservoir water surface to elevation 4297.0. These enlargements would provide an additional 87,500 acre-feet of flood storage. The hydraulic considerations required that (a) the gates in their present setting and without major change be used satisfactorily for irrigation releases when the reservoir was at or below elevation 4275.0, and (b) the new structure and spillway should be capable of handling a discharge of about 56,000 cfs at reservoir elevation 4297.0.

Model studies were made to assure the proper hydraulic operation of the new structure both with and without gate control, and to aid in the preparation of a discharge chart for flood routing and irrigation releases.

THE MODEL

A study of the drawings of the prototype structure indicated that the reproduction of one bay in the model would be adequate since the operation of the spillway chute was not a part of the study. A model, built to a scale of 1:36, was sufficiently large to permit accurate calibration and determination of other hydraulic characteristics of the system. The headbox was 13 feet wide and 12 feet long. Water was furnished to the model through the laboratory venturi meters where accurate discharge measurements down to 0.4 cfs (3,100 cfs prototype) could be made. The one-bay-wide section of the entrance and spillway chute floor was reproduced for a prototype distance of 106 feet upstream and 137 feet downstream from the gate (Figure 3). A portion of the floor representing 86-1/4 feet upstream and 57-3/4 feet downstream from the gate was of sheet metal for ease of removal and replacement. The initial hood was also of sheet metal. The remainder of the model was of marine plywood with the piers of treated sugar pine.

For the calibration of the center bay, and the development of the pertinent features of the enlargement, two parallel vertical walls were extended upstream from the two piers bounding the center bay, with the upstream ends of the walls curved out into the reservoir to assure parallel flow into the test section (Figure 4A and B). The radial gate was adjusted by hand and wedged into place. A point gage near the center of the headbox was used for reservoir elevation measurements. Piezometers in the spillway floor and in the hoods and drains were used to determine the pressure head at various critical points on the model.

THE INVESTIGATION

Preliminary Modifications

The preliminary design included a headwall extending 19 feet above the upstream end of the piers, 8 buttresses 18 inches thick and 17.67 feet on centers parallel to the spillway center line and reaching upstream 60 feet from the headwall, and a new floor 0.21 foot higher than the original spillway crest and extending upstream from the old crest for 58.5 feet. The sloping upstream edge of the buttresses supported a hood extending upstream from the headwall to a position where the lowest point of the hood was 12.5 feet above the floor. The original piers and radial gates were not changed (Figure 3).

Preliminary Operation

The uncontrolled flow through the system was smooth at all reservoir elevations (Figure 6A), and the discharge at maximum reservoir (elevation 4297.0) was 53,500 cfs (Figure 5). However, when the radial gate was used for control, the operation was unsatisfactory for all reservoir levels above the lower point of the hood, elevation 4266.71. The surging action between the gate and the hood was so violent that water topped the piers adjacent to the gate and waves traveled upstream from the hood into the forebay (Figure 6B).

Roofed Passages

Level roofs were installed under the hood starting at the upstream edge of the hood at elevation 4266.71 and extending downstream for 15, 25.9, 33.4, and 39 feet (Figure 7A). Flow was unsatisfactory with the three shorter lengths because of the same type of objectionable surging action as that encountered with the sloping hood (Figure 8A). With the 39-foot-long roof, which reached to within 2.4 feet of the face of the radial gate, the flow was satisfactory when controlled by the gate (Figure 8B); however, the designers considered the roof to be impractical for prototype installation because construction would be very difficult.

A wave suppressing curtain wall was installed against the downstream end of the buttresses, extending from the headwall down to within 14 feet of the floor (Figure 7B). When the flow was gate-controlled, the operation with the curtain wall was no better than that without it. Violent surging occurred between the wall and the hood and downstream between the wall and the gate.

The difficulty apparently originated with the hood, therefore, it was removed from the model.

Orifices

Since the buttresses were necessary to support the headwall, a new set was made (Figure 9A) to replace the old ones which were removed with the discarded hood. A curtain wall was installed at the downstream end of the buttresses extending from the headwall down to elevation 4266.71 (Figure 9B). For free flow, this design operated very well; but when the gate controlled the flow and the reservoir was above elevation 4267, the water surged back and forth upstream from the gate. From observation of the action of the water in the preliminary design, and this design with the curtain wall, it was evident that the top of the flow passage should be at elevation 4275, or above, so that the flow would be positively controlled by either the opening or the gate, but would not oscillate between the two.

Figure 9 shows various plans which were intended to restrict the discharge to approximately 56,000 cfs for reservoir elevation 4297.0 and have the top of the opening no lower than elevation 4275. These designs were model-tested to determine the flow characteristics when the discharge was gate-controlled.

To pass the maximum discharge of 56,000 cfs, the open area should be roughly 200 square feet for each of 9 openings, assuming one opening between adjacent buttresses. The design shown in Figures 9C and 10A consisted of rectangular orifices 9.35 feet wide, 20.79 feet high, and 17.67 feet on centers. For small discharges, with the gate controlling the reservoir to elevation 4275.0, the flow was good throughout the system. For larger gate openings, the orifices partially controlled the flow and a rough water surface resulted from the water surging into the area behind the partitions separating the orifices. For uncontrolled flow at high reservoir elevations, huge fins of water issued from the orifices, resulting in unacceptably rough flow conditions in the vicinity of the gate and gate counterbalances (Figure 10B).

Figure 9D shows 3 trapezoidal orifices per bay with the top of each the full width (16.17 feet) between buttresses and 3.35 feet wide at the floor. The flow was acceptable for all gate-controlled discharges; however, the uncontrolled flow at high reservoir elevations was very rough in the vicinity of the gate and counterbalances.

A control section, as shown in Figure 9E, consisted of 3 trapezoidal orifices per bay full width between the buttresses at the bottom and 3.35 feet wide at elevation 4275. The gate-controlled flow with this design was satisfactory. The uncontrolled flow was unsatisfactory for all reservoir elevations above 4275 because of excessively rough water in the vicinity of the gate and gate counterbalances.

A "T" shaped opening 16.17 feet wide between elevations 4275.0 and 4267.9, and 6.1 feet wide for the remaining 13.69 feet down to the floor (elevation 4254.21) is shown in Figure 9F. The gate-controlled flows were very good with this design; however, for free discharge, the flow was rough, although acceptable, in the vicinity of the gate.

The orifices shown in Figure 9G have the same dimensions as those in the previous test, but with the widest portion at the bottom. Free flow through these openings was so violently rough that tests were discontinued on this arrangement.

In view of the above tests, it was concluded that the openings between piers should not be separated by partitions wider than the buttresses. The bottom of the curtain wall could not extend below elevation 4275 as determined by the preliminary tests. The area of the openings was determined by the free discharge requirement--56,000 cfs at reservoir elevation 4297.0. The next logical step in constricting the flow area was to place a sill across the approach channel beneath the curtain wall.

Recommended Design

To provide the proper flow area, a sill was placed across the channel directly under the curtain wall at Station 2+69.00, with its top at elevation 4261.35 (Figure 9H). The buttresses upstream from the center lines of each pier were extended downstream to the pier nose. The general flow with this design was very good for all reservoir elevations whether gate-controlled or free flow through the orifices. The only adverse condition consisted of high, thin fins of water which started at the pier nose, clung to the walls of the piers for about 40 feet, and were about 8-1/2 feet above mean water level at the highest point. These objectionable fins were eliminated by placing an 8-foot-wide section in the buttresses upstream from each pier, causing the jet to contract and flow smoothly past the pier.

A new control passage 44.61 feet wide and with the curtain wall down to elevation 4275.00 and the sill up to elevation 4260.75, was installed in the model for calibration and pressure tests. The results of these studies indicated that the design was sound. The flow was good for all conditions of discharge, and the pressures on the spillway were positive in all cases.

The many problems relating to the stability of the new structure, the minimum revisions necessary so that the existing prototype structure could accommodate the new installation, and the hydraulic characteristics of the design, were discussed in conference with the design personnel. A design agreeable to all concerned was prepared, built to scale, and tested for both the center bay and one side bay (Figures 11, 12A, and 14). It was deemed unnecessary to test the right bay since it was sufficiently similar to the left bay that operation of the two should be identical. This design is referred to here as the recommended design.

Flow Conditions--Recommended Design

Center bay. The flow through the center bay was good for all reservoir elevations and gate positions (Figures 12B and 13A).

Left bay. Gate-controlled flow through the left bay was good for all reservoir elevations up to 4275.0.

Free flow through the left bay was good up to about reservoir elevation 4287; at this point, a vortex formed in the area between the left buttress and the warped entrance wall. This vortex persisted as the reservoir raised to elevation 4297 and was most pronounced at about elevation 4288.5 (Figure 13B). Although there would be a tendency for the vortex to form in the prototype, it was believed that it would not be dangerous to the structure nor cause adverse flow conditions downstream.

In the original prototype installation, a flood of 42,000 cfs (1942) caused excessive scour to the spoil bank upstream from the left entrance wall. The reservoir elevation for this discharge was about 4275.2 with a velocity of about 10 fps at the upstream end of the spoil bank. With the recommended design, the free discharge for this elevation will be 27,000 cfs, the approach velocities will be much lower, about 6.4 fps, and the tendency to scour will be greatly reduced. These two conditions are shown by Figure 15A and B.

Discharge--Recommended Design

During calibration, the guide walls to the center bay were parallel and extended 100 feet (prototype) into the reservoir, then continued on a 36-foot radius to make a smooth approach and parallel flow into the orifices and gate area (Figure 12A). The approach to the left bay consisted of the same guide wall on the right as for the center bay, and with the prototype warped wall and spoil bank of the left approach area (Figure 14A and B).

Calibration was made for gate-controlled flow for reservoir elevations between the top of the cross sill, elevation 4259.0, and the bottom of the curtain wall, elevation 4275.0, and for free flow for reservoir elevations between 4259.0 and 4297.0. Figure 16 shows the results of these tests.

Since the top of the cross sill is 5 feet above the elevation of the gate seats, there is a range of reservoir elevations and gate openings where the gates will back water up against the downstream face of the sill, but the sill will continue to control the discharge. For example, if the reservoir water surface was at elevation 4261.0, the free flow discharge would be 1,400 cfs, and, although the gate would be in the stream for gate openings between 9 inches and 1 foot, the discharge would not change. For this reservoir elevation, the gates would control the flow at openings smaller than 9 inches.

For higher reservoir elevations (above 4262.2) the gates will control the flow if they are in the stream. For example, free discharge for reservoir elevation 4271.8 is 19,200 cfs, and the free water depth at the point of contact for the gates is 7 feet. If the gates are lowered to touch the stream and thus control the flow (7.0-foot gate opening) the discharge will be reduced to 16,500 cfs. The gate may then be raised and will continue to control the discharge up to a gate opening of 8.75 feet and a discharge of 18,600 cfs. If the gates are raised further, the stream at the gate will drop to 7 feet deep; the orifices will control the flow, and the discharge will again be 19,200 cfs.

These conditions must be taken into account when determining the quantity of water being released through the spillway.

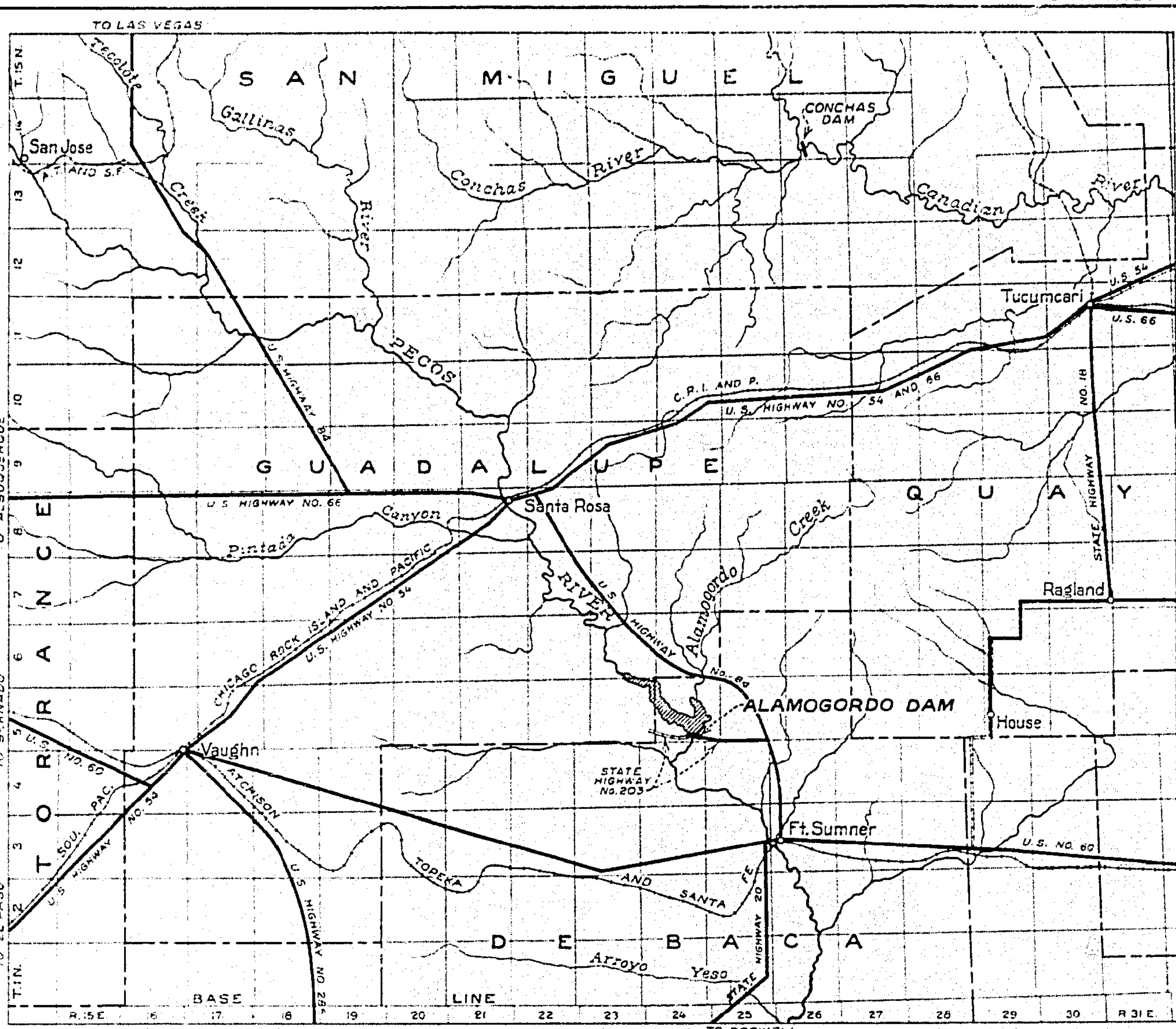
Pressure Conditions--Recommended Design

The pressures on the sill below the headwall and on the parabolic floor of the original spillway were measured by means of piezometers installed during construction of the model. With the maximum discharge of 56,000 cfs, the sill pressures reached a minimum of about 2 feet above atmospheric (Figure 17). Although this is about 12 feet less than the water depth above the sill, it is in the safe range and should cause no concern.

For maximum discharge, the pressures on the spillway floor, just downstream from the sill, were quite high, nearly equal to the total head. Below the sill, the pressure decreased gradually to a minimum of positive 2-1/2 feet at Station 3+07.0, and then increased to slightly higher than the water surface farther downstream (Figure 17). The pressures are considered safe for any operating condition.

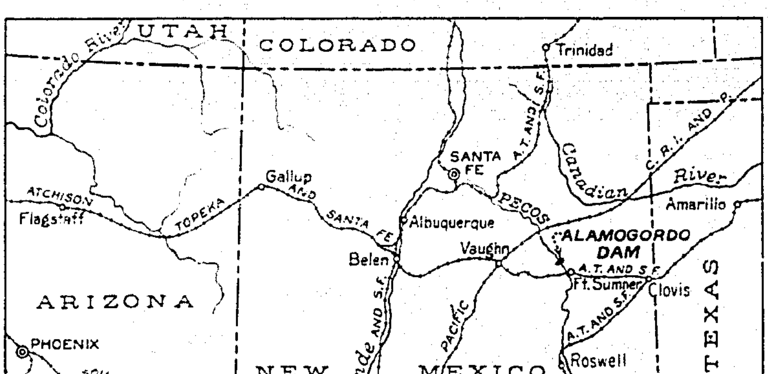
Underdrain Outlet Hoods

Two different outlet hoods, one adjacent to a pier and the other in the open chute between the piers, were suggested for the underdrains which drain water from under the slab upstream from the gates onto the spillway face (Figure 18). The model tests were concerned with the determination of the station of minimum pressure on the spillway face and a measurement of the pressure on the downstream face of the underdrain hood. From the spillway pressure curve (Figure 17) it was determined that the underdrain outlet opening should be located about Station 3+10.0 for optimum pressure conditions and that a flap or check gate would not be necessary to prevent backflow into the underdrain piping. Of the two drain hoods, the one located in the open chute produced a slightly lower pressure on the downstream face; however, the one located adjacent to the pier was used, since it would also operate satisfactorily and would be simpler to construct in this particular installation.

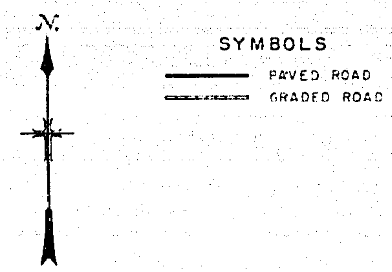


VICINITY MAP

5 0 5 10 15 20
SCALE OF MILES



INDEX MAP

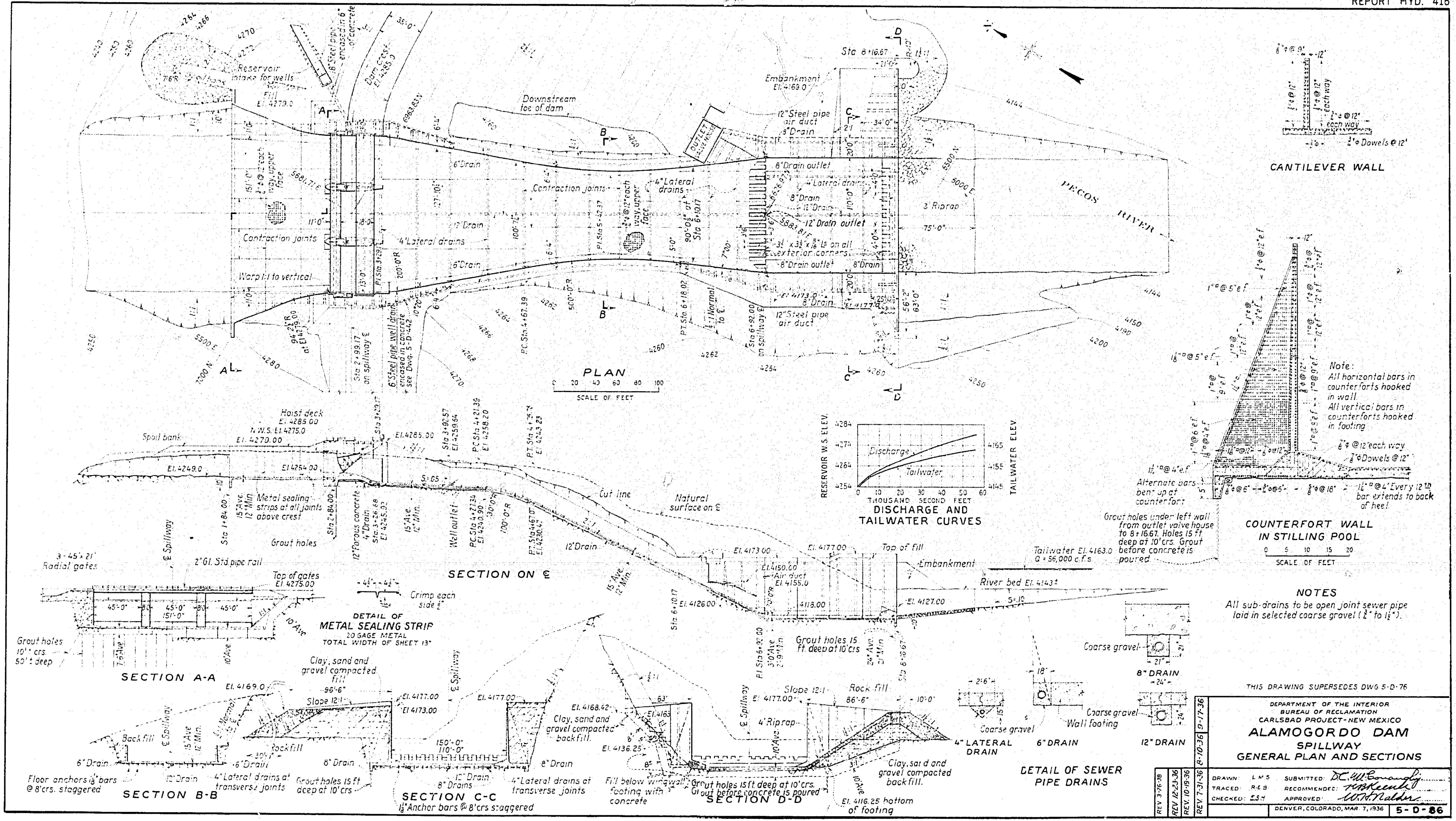


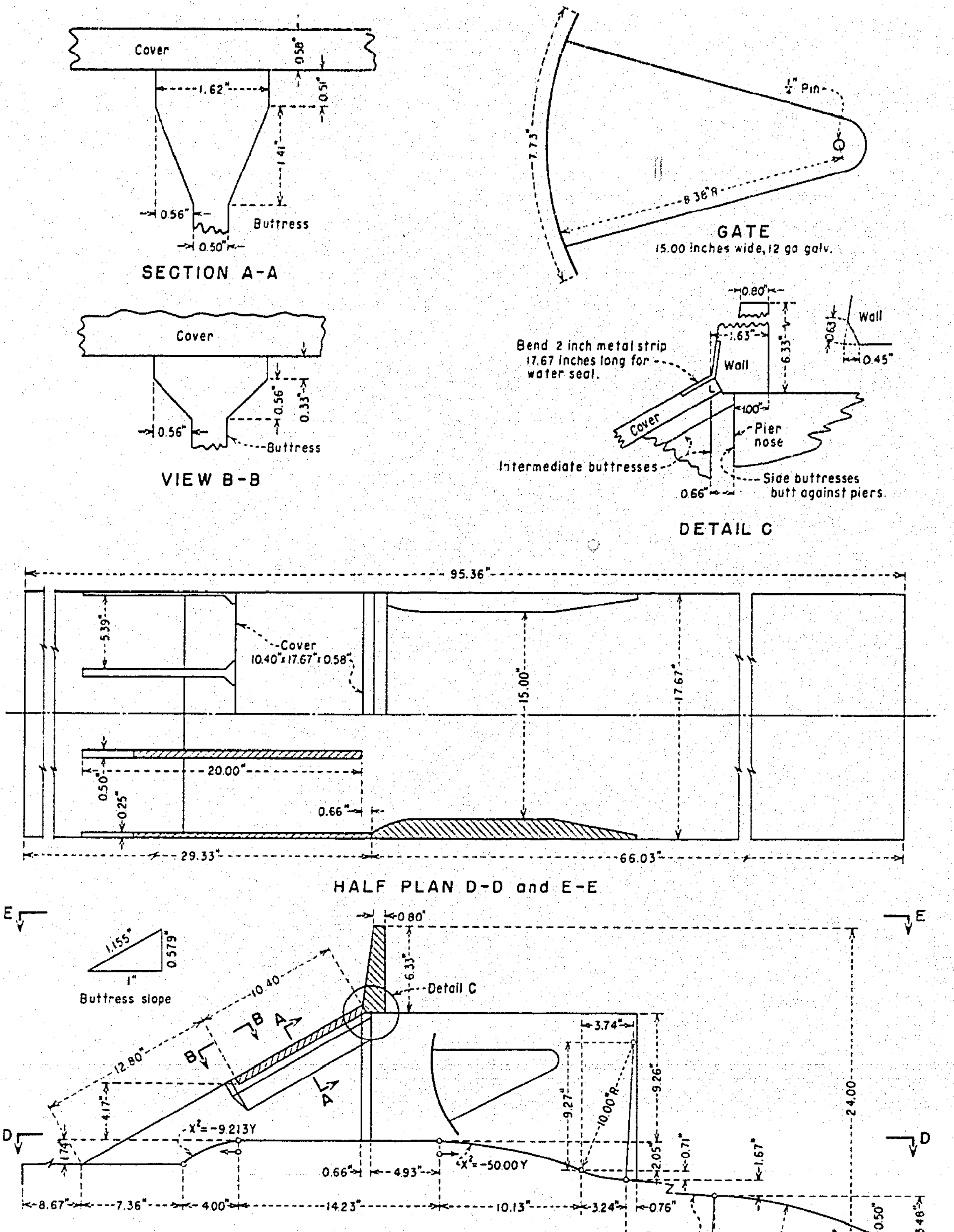
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CARLSBAD PROJECT—NEW MEXICO

ALAMOGORDO DAM
LOCATION MAP

DRAWN: D.R.B., E.C.P. SUBMITTED: Fred C. Walter
TRACED: D.C.K., B.F.W. RECOMMENDED: T.W. Mermel
CHECKED: RMR APPROVED: O. A. Bergelund

DENVER, COLORADO, FEB 1, 1955 | 5-D-683


PLAN
SCALE OF FEET
SECTION ON ℄
SECTION A-A
SECTION B-B
SECTION C-C
SECTION D-D
DETAIL OF METAL SEALING STRIP
20 GAGE METAL
TOTAL WIDTH OF SHEET 13"
DISCHARGE AND TAILWATER CURVES
RESERVOIR W.S. ELEV.
TAILWATER ELEV.
THOUSAND SECOND FEET
Discharge
Tailwater
CANTILEVER WALL
COUNTERFORT WALL IN STILLING POOL
Note: All horizontal bars in counterforts hooked in wall. All vertical bars in counterforts hooked in footing.
NOTES
All sub-drains to be open joint sewer pipe laid in selected coarse gravel (3/4" to 1 1/2").
DETAIL OF SEWER PIPE DRAINS
4" LATERAL DRAIN
6" DRAIN
8" DRAIN
12" DRAIN
PECOS RIVER
Reservoir intake for wells
Downstream toe of dam
Contraction joints
4" Lateral drains
3-45'x21' Radial gates
Hoist deck El. 4285.00
N.W.S. El. 4275.0
Tailwater El. 4163.0
Q = 56,000 c.f.s.
River bed El. 4143±
Grout holes under left wall from outlet valve house to 8+16.67. Holes 15 ft deep at 10' crs. Grout before concrete is poured.
THIS DRAWING SUPERSEDES DWG 5-D-76
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CARLSBAD PROJECT-NEW MEXICO
ALAMOGORDO DAM
SPILLWAY
GENERAL PLAN AND SECTIONS
DRAWN: L.M.S.
TRACED: R.E.B.
CHECKED: E.S.H.
SUBMITTED
RECOMMENDED
APPROVED
DENVER, COLORADO, MAR. 7, 1936
5-D-86



$X^2=-50.00Y$	
X	-Y
0	0
1.0	0.02
2.0	0.08
3.0	0.18
4.0	0.32
5.0	0.50
6.0	0.72
7.0	0.98
8.0	1.28
9.0	1.62
10.0	2.00
10.13	2.05

$X^2=-9.213Y$	
-X	-Y
0	0
0.5	0.03
1.0	0.11
1.5	0.24
2.0	0.43
2.5	0.68
3.0	0.98
3.5	1.33
4.0	1.74

CARLSBAD PROJECT – NEW MEXICO

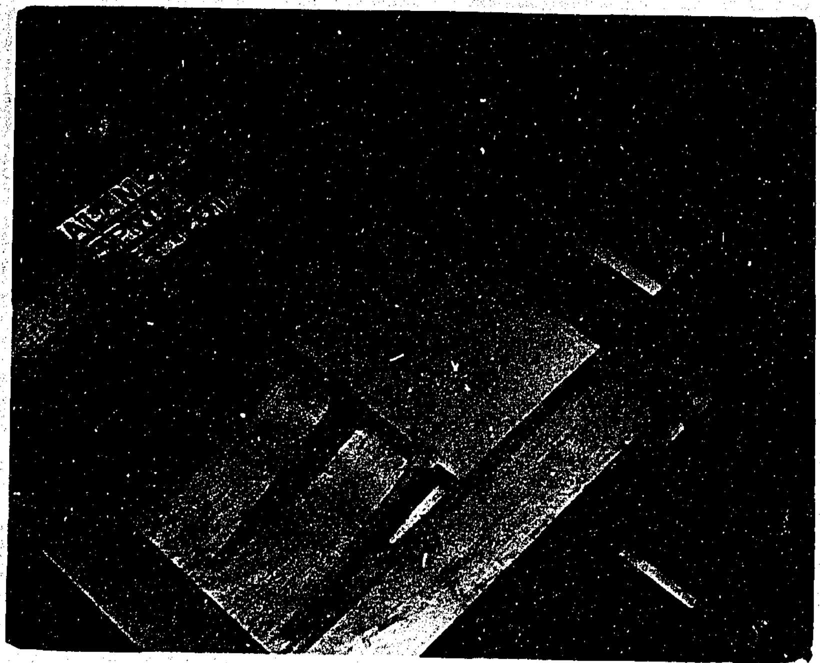
ALAMOGORDO DAM ENLARGEMENT

SPILLWAY MODIFICATIONS

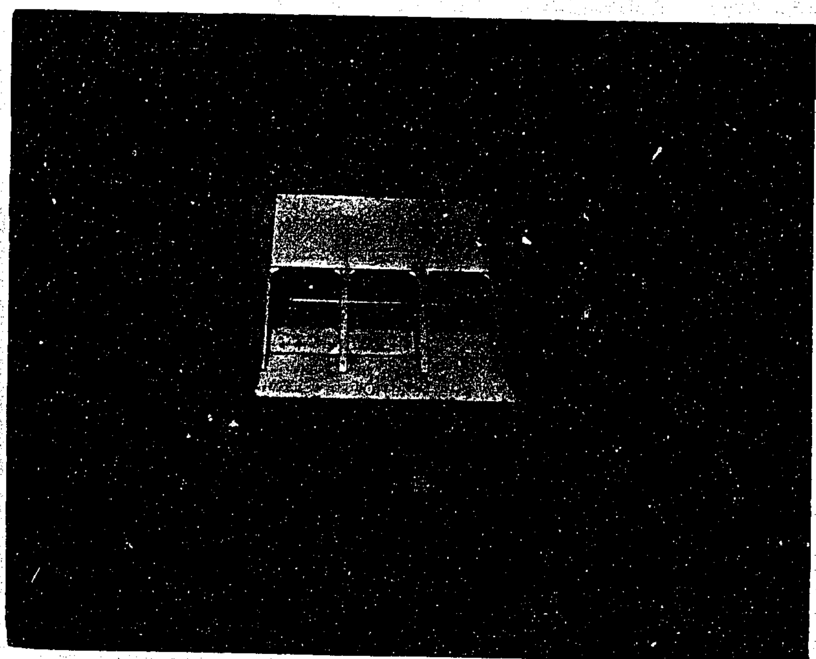
SPILLWAY PLAN AND SECTIONS

PRELIMINARY DESIGN

MODEL SCALE – 1:36



A The buttresses, hood, headwall and gate from above.

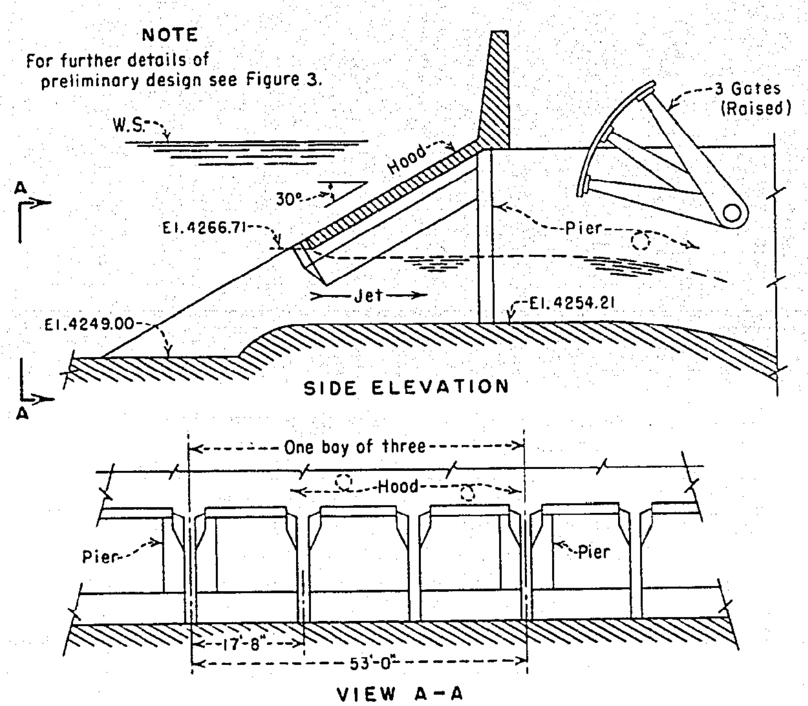


B Looking downstream at the entrance from the reservoir area.

ALAMOGORDO DAM

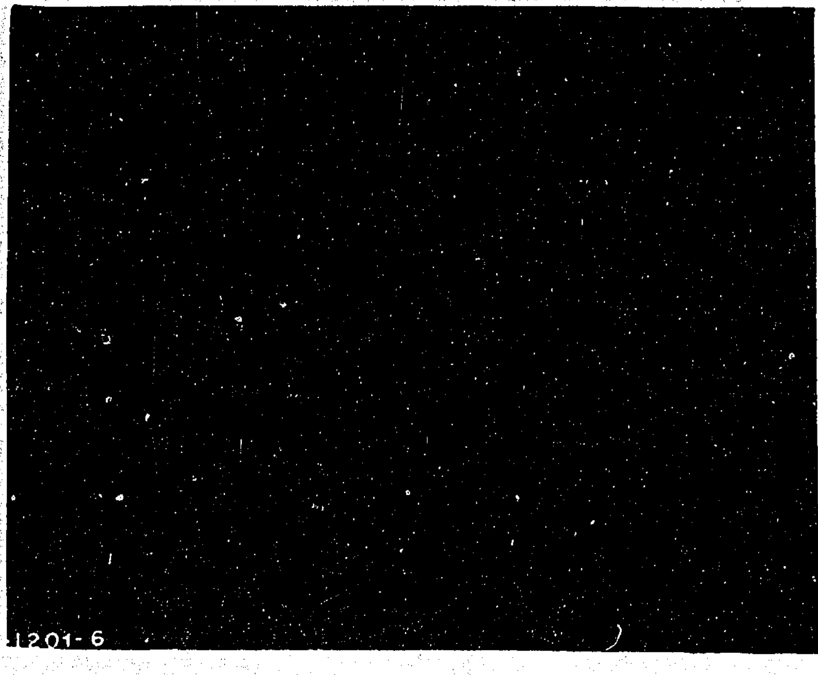
Preliminary design, center bay

NOTE
For further details of preliminary design see Figure 3.

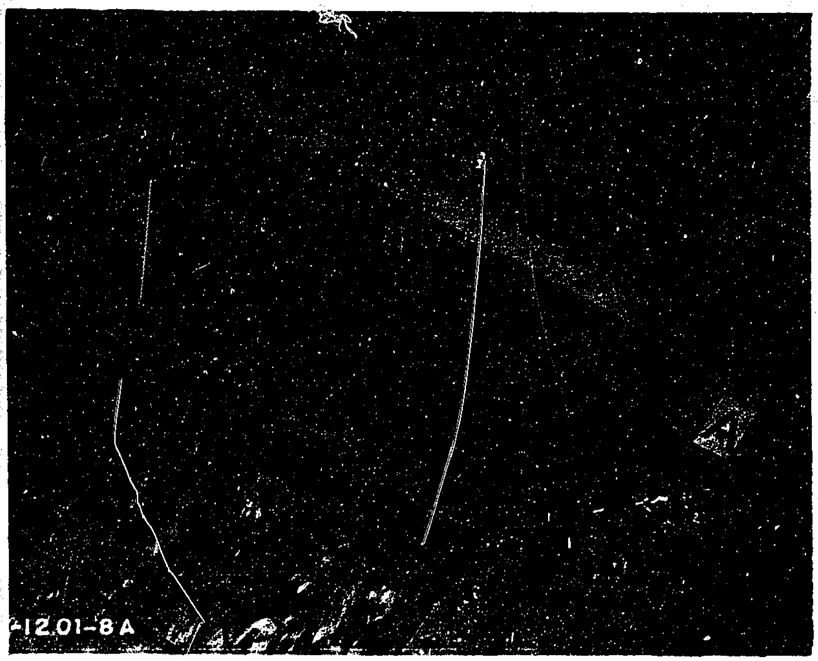


CARLSBAD PROJECT – NEW MEXICO
ALAMOGORDO DAM ENLARGEMENT
SPILLWAY MODIFICATIONS
DISCHARGE CURVE
PRELIMINARY DESIGN
MODEL SCALE 1:36

575



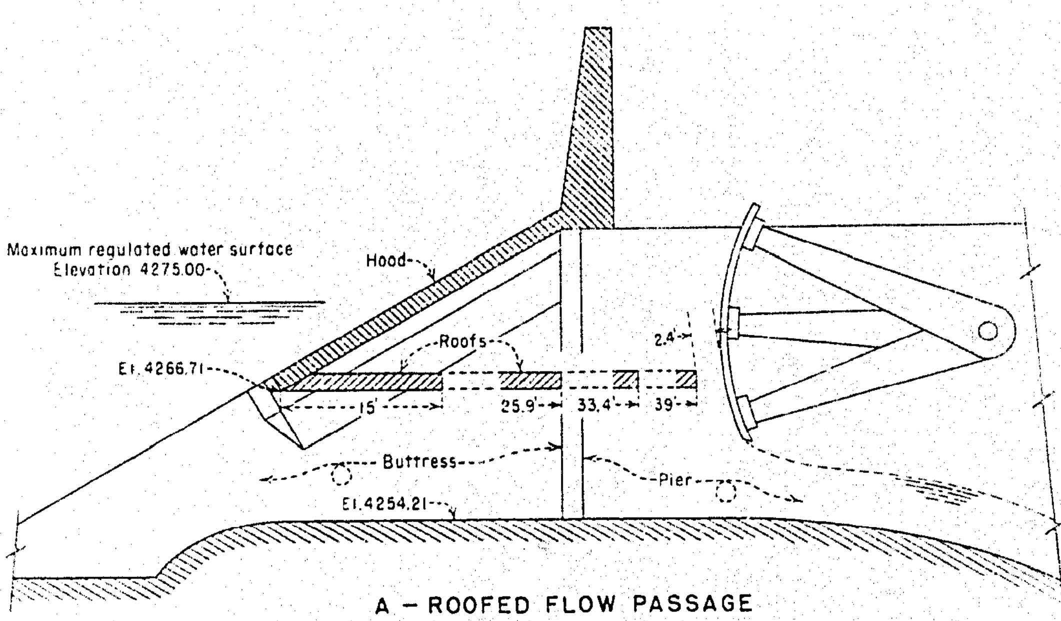
A Reservoir elevation 4270.4
Discharge = 8400 cfs (one bay)
Gate out of the stream



B Reservoir elevation 4275.0
Discharge = 8400 cfs (one bay) controlled
by Gate opened $12\frac{1}{2}$ feet.

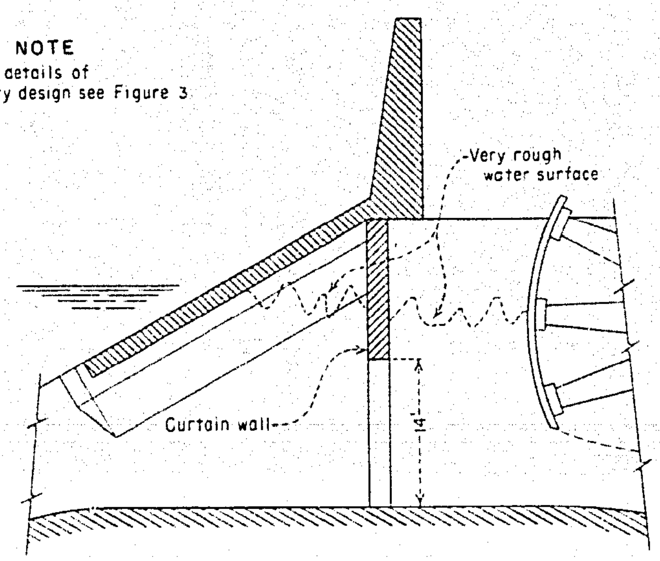
ALAMOGORDO DAM

Preliminary design - center bay



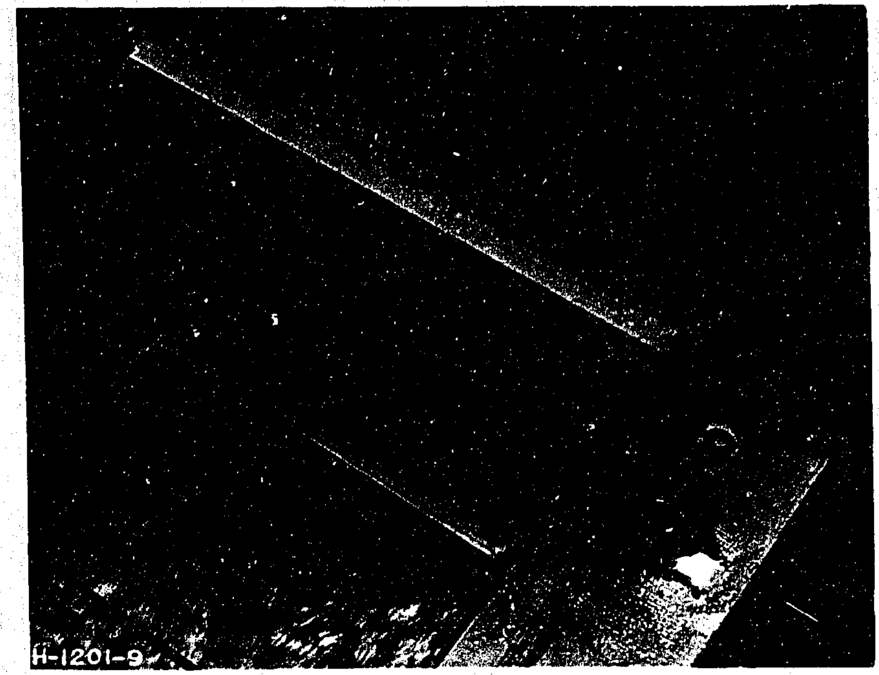
A – ROOFED FLOW PASSAGE
WITH PRELIMINARY DESIGN FLOOR AND HOOD

NOTE
For further details of preliminary design see Figure 3

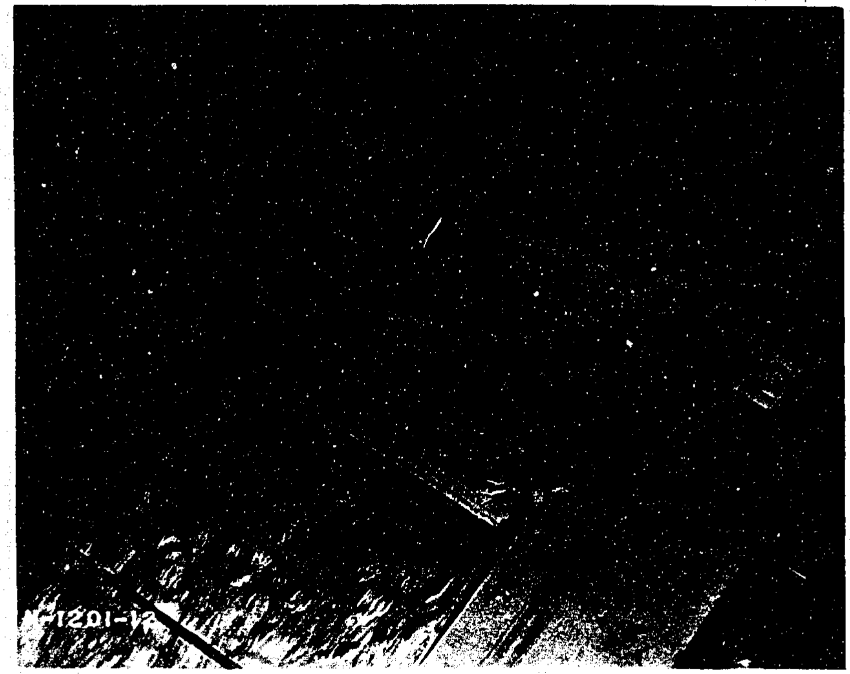


B – CURTAIN WALL
WITH PRELIMINARY DESIGN FLOOR AND HOOD

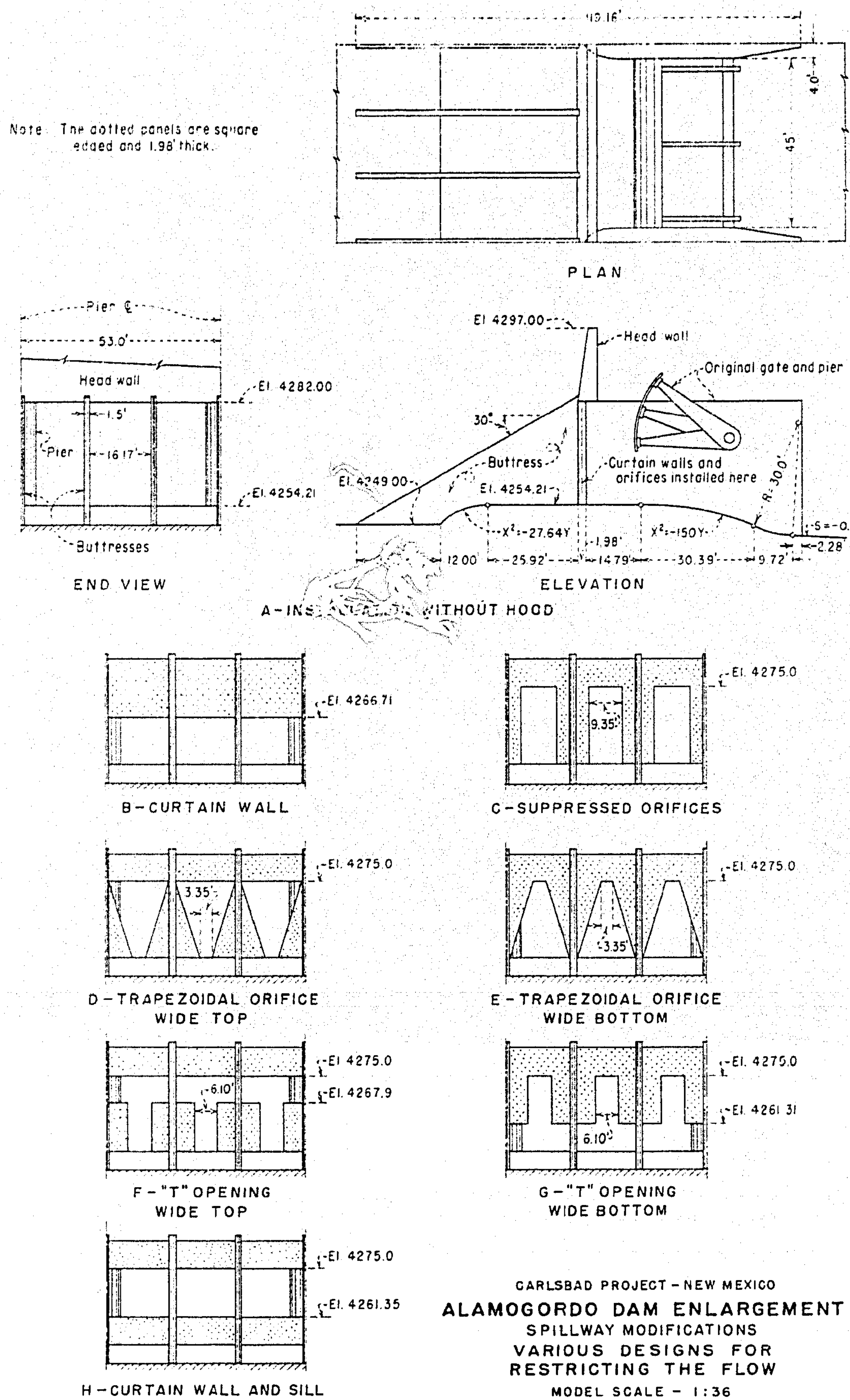
CARLSBAD PROJECT – NEW MEXICO
ALAMOGORDO DAM ENLARGEMENT
SPILLWAY MODIFICATIONS
ROOFED FLOW PASSAGES
AND CURTAIN WALLS
MODEL SCALE – 1:36



A Roof of flow passage under hood 25.9 feet long



B Roof of flow passage under hood 39.0 feet long
ALAMOGORDO DAM - Center bay
Reservoir elevation 4275.0
Discharge - 8400 cfs (one bay) controlled
by Gate opened 12½ feet.



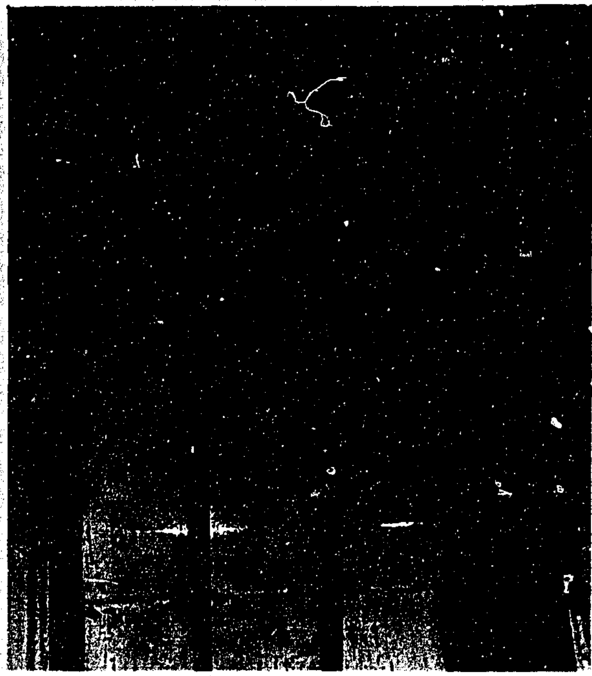
CARLSBAD PROJECT - NEW MEXICO

ALAMOGORDO DAM ENLARGEMENT

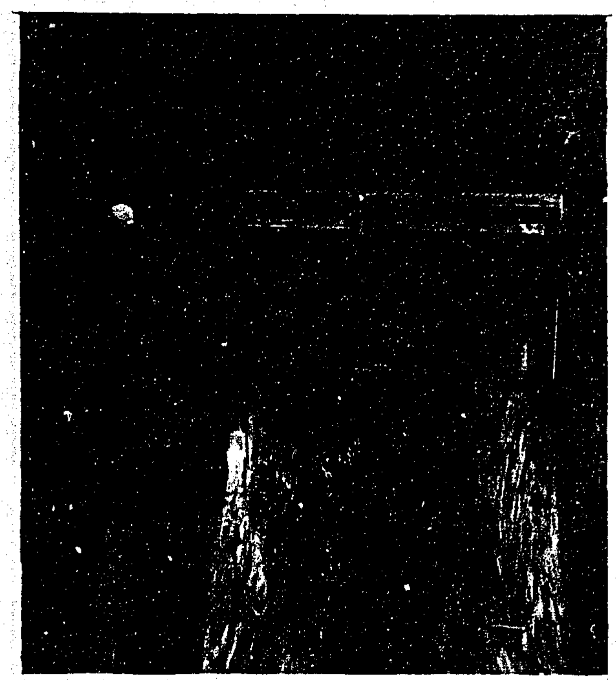
SPILLWAY MODIFICATIONS

VARIOUS DESIGNS FOR RESTRICTING THE FLOW

MODEL SCALE - 1:36



A Looking downstream

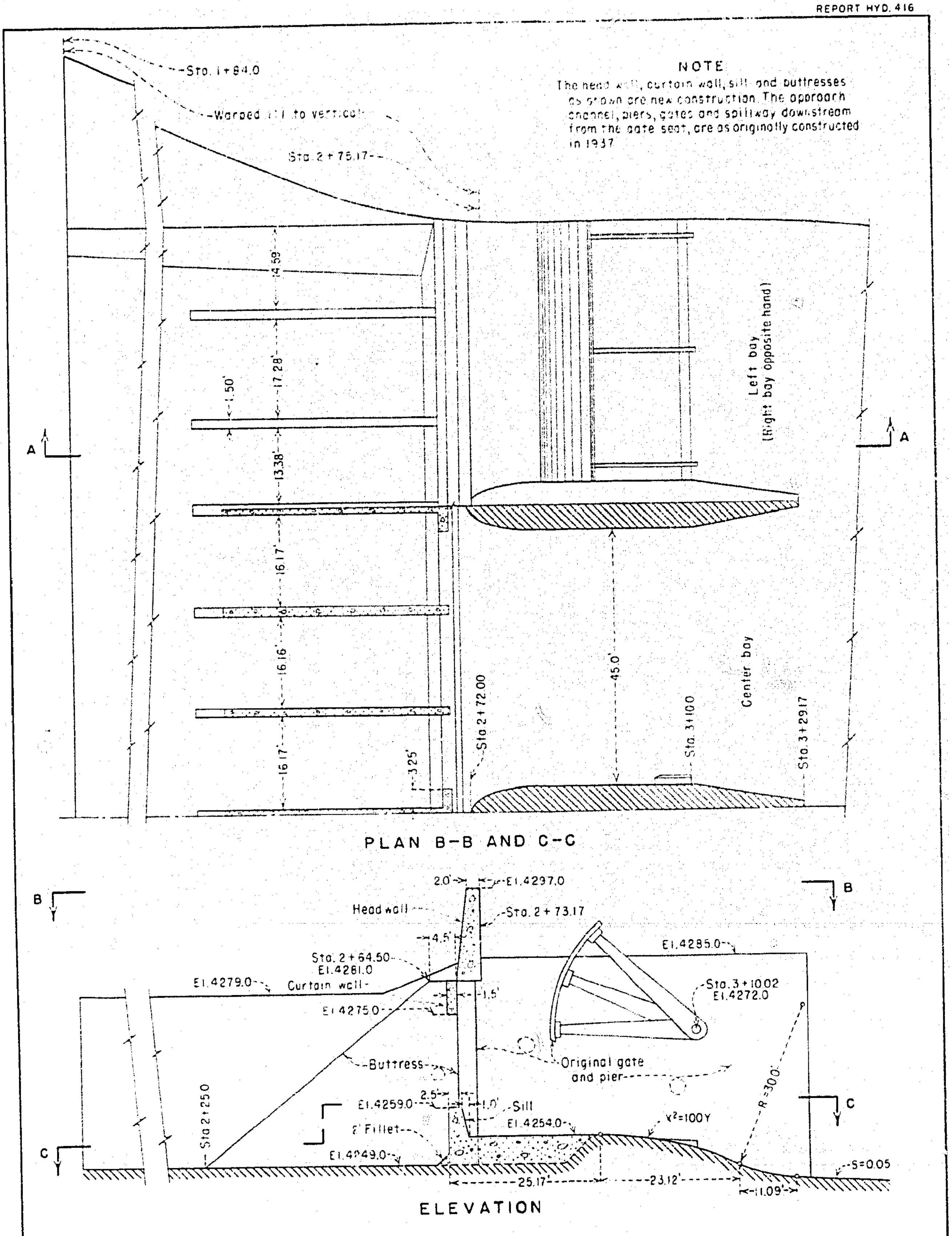


B Reservoir elevation 4296.3
Discharge - 17,200 cfs (one bay)

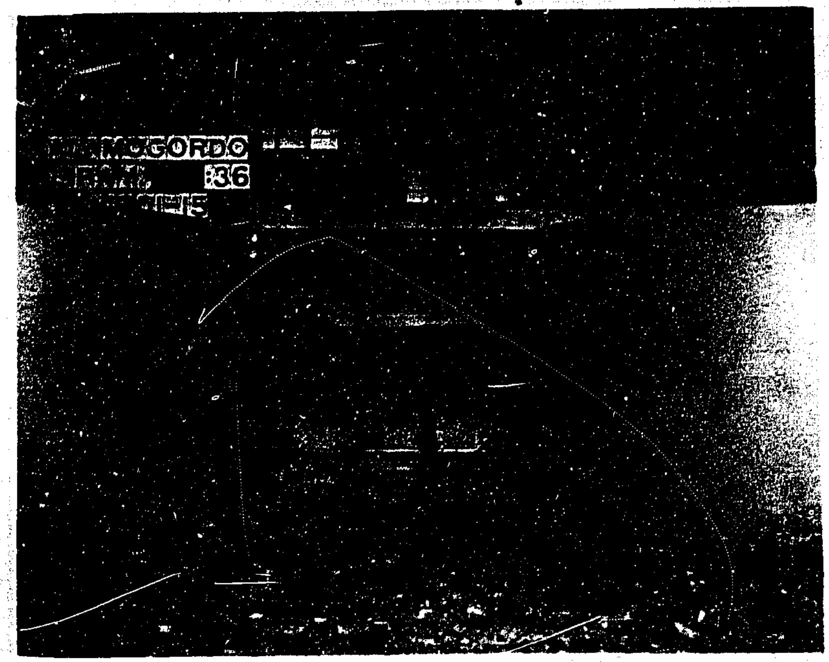
ALAMOGORDO DAM

Rectangular orifices 9.35' wide x 21' high
3 per bay

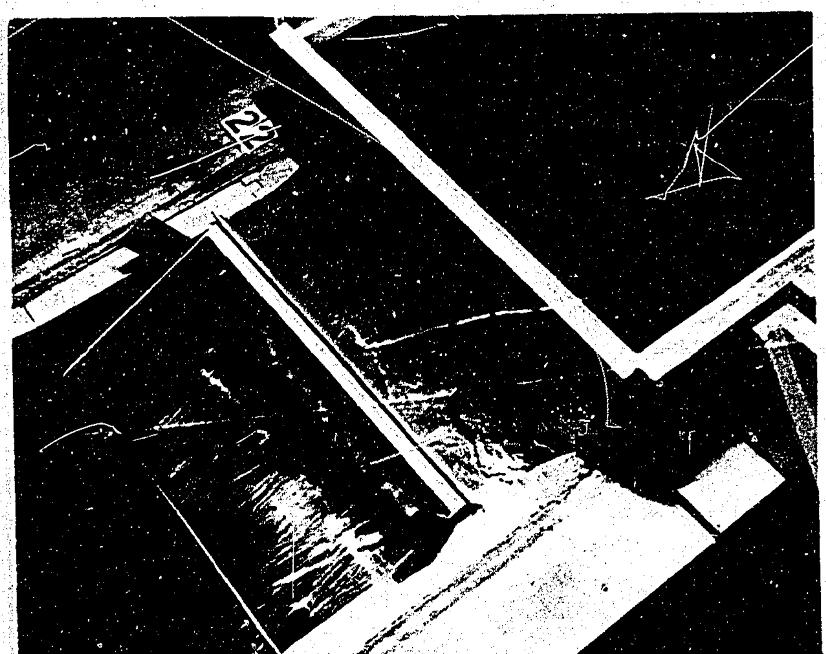
FIGURE II
REPORT HYD. 416



CARLSBAD PROJECT – NEW MEXICO
ALAMOGORDO DAM ENLARGEMENT
SPILLWAY MODIFICATIONS
RECOMMENDED DESIGN
PLAN AND ELEVATION
MODEL SCALE – 1:36



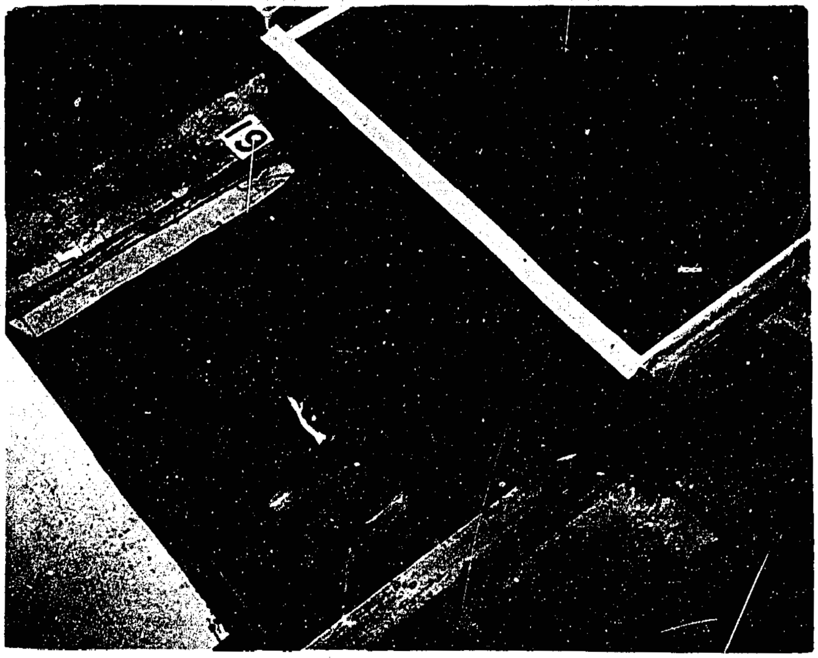
A Looking downstream at the entrance from the reservoir area.



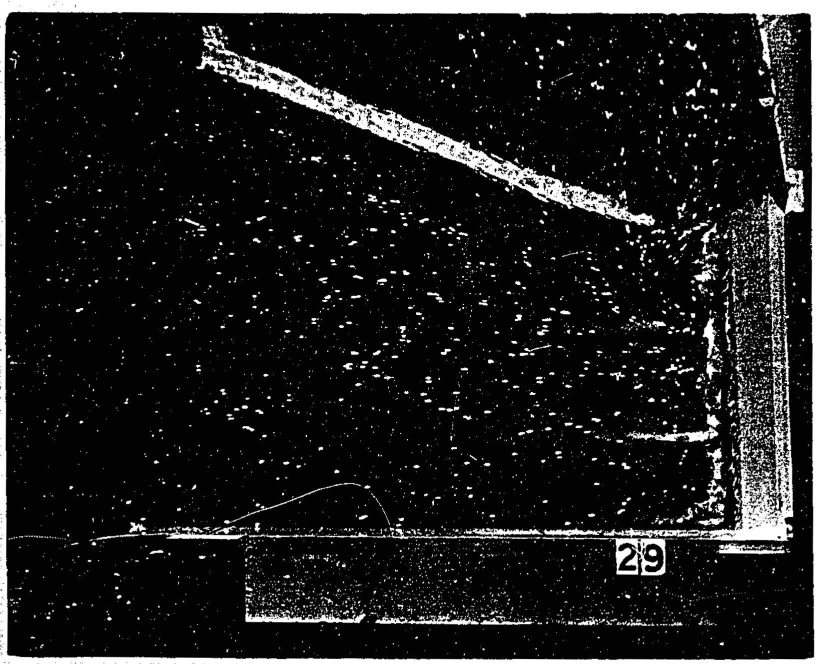
B Reservoir elevation 4275.0
Discharge - 6,650 cfs (one bay)
Gate raised $7\frac{1}{2}$ feet

ALAMOGORDO DAM

Recommended design, center bay



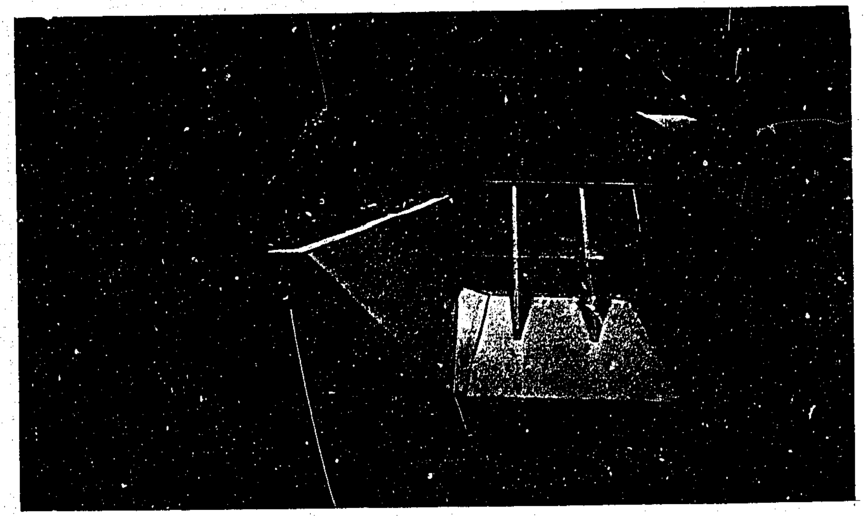
A Center bay - Reservoir elevation 4297.1
Discharge - 18,750 cfs (one bay)



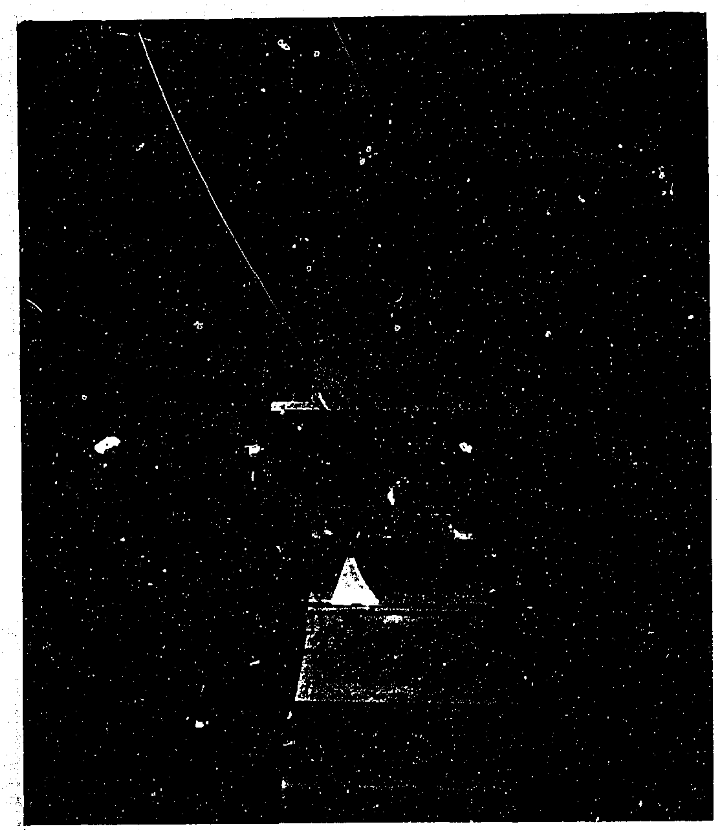
B Left bay - Reservoir elevation 4288.5
Discharge 15,680 cfs (left bay only)

ALAMOGORDO DAM

Recommended design



A Looking downstream at the entrance from the reservoir area.

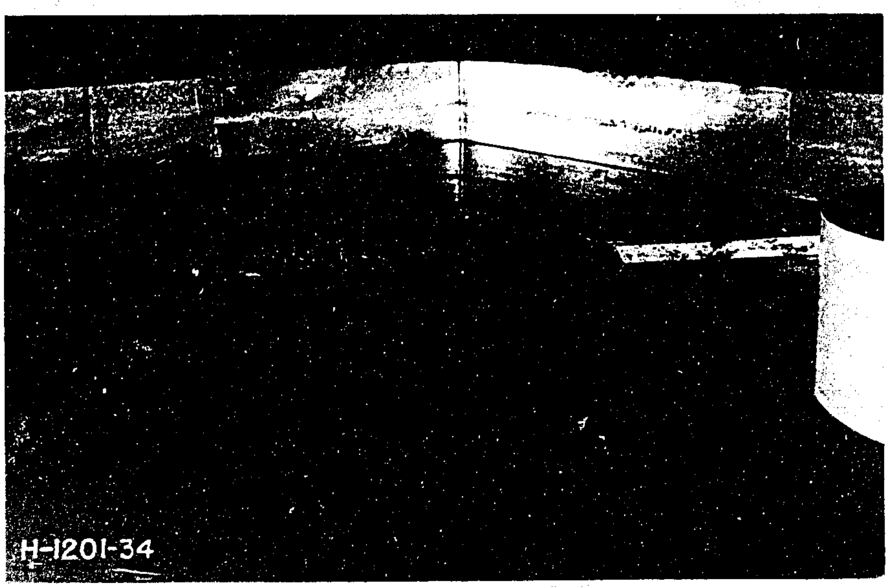


B View from above

ALAMOGORDO DAM

Recommended design - left bay

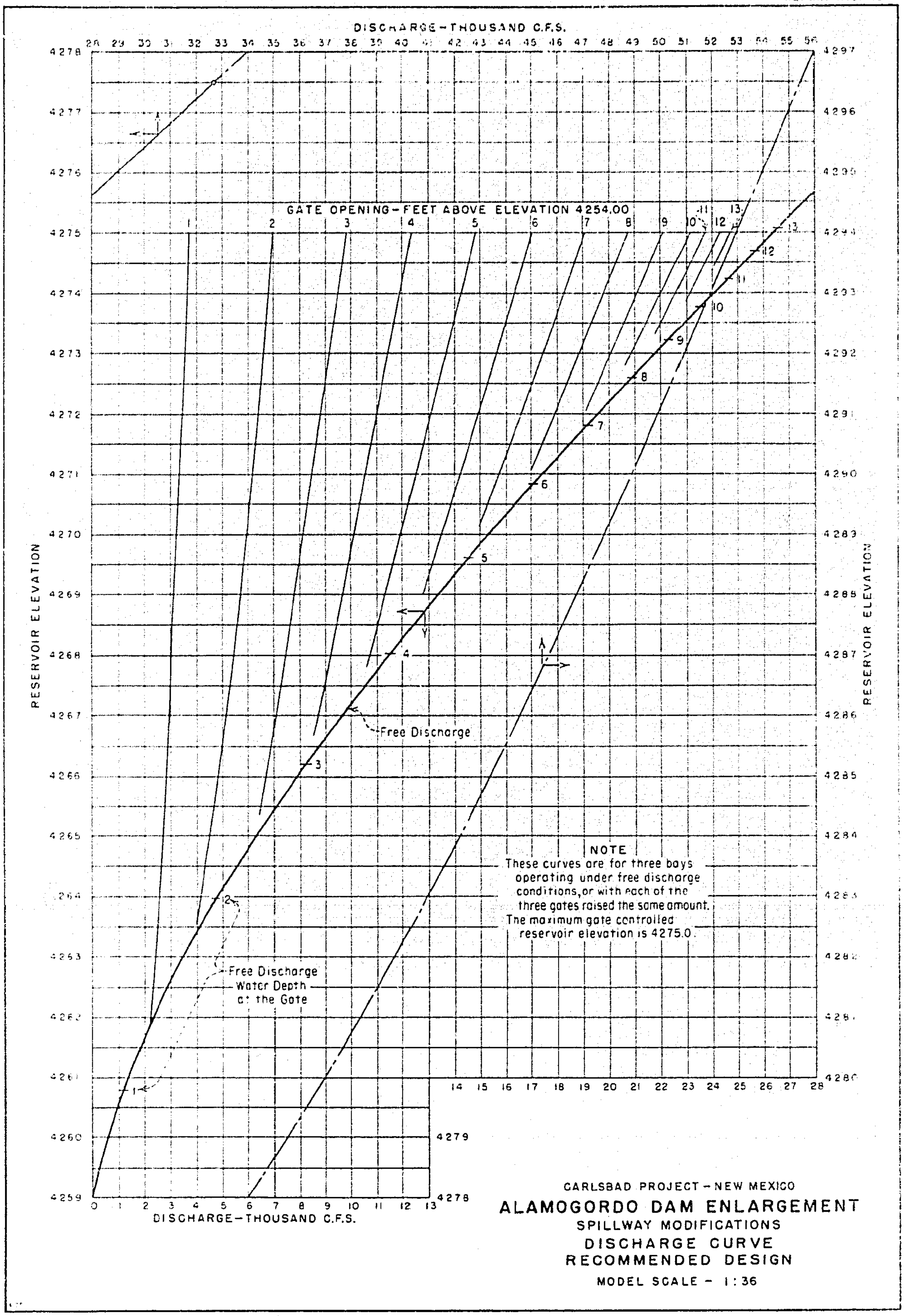
A Prototype - original installation
View towards left approach wing wall
Reservoir elevation 4275.2
Discharge - 42000 cfs



B Recommended design - 1:36 scale model
Same view as prototype
Reservoir elevation 4276.3
Discharge - 29,700 cfs (total)

ALAMOGORDO DAM

Left approach wall
Original prototype - recommended model



CARLSBAD PROJECT - NEW MEXICO

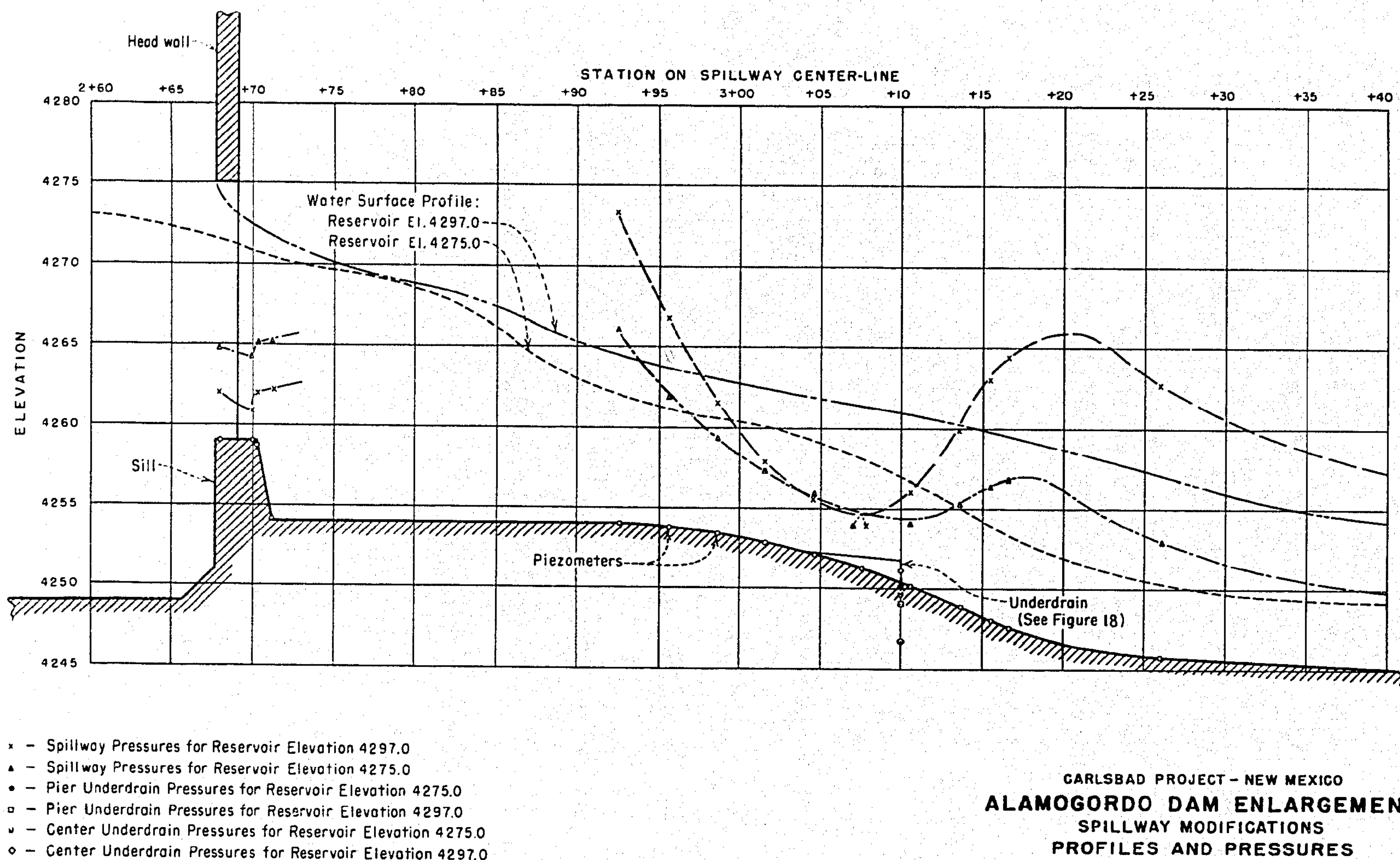
ALAMOGORDO DAM ENLARGEMENT

SPILLWAY MODIFICATIONS

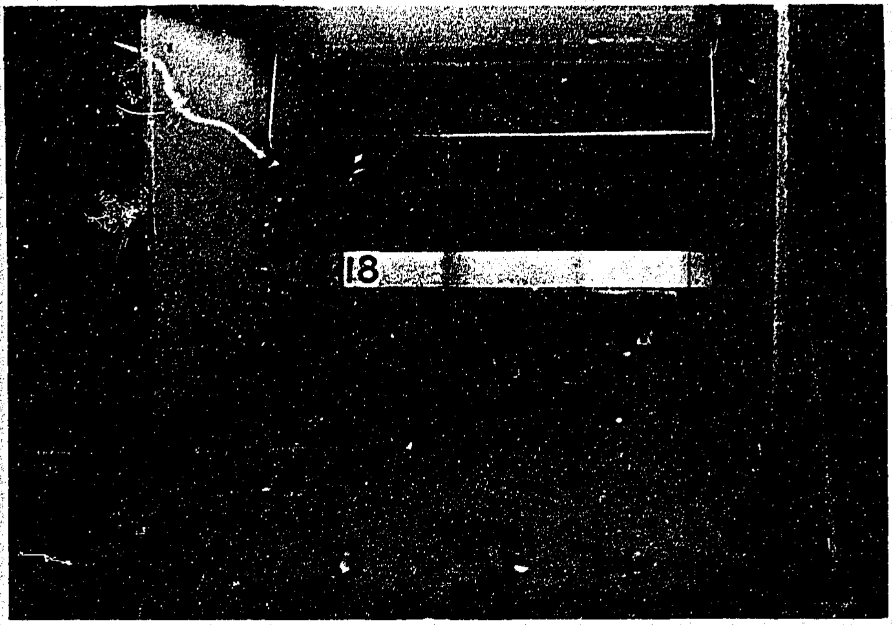
DISCHARGE CURVE

RECOMMENDED DESIGN

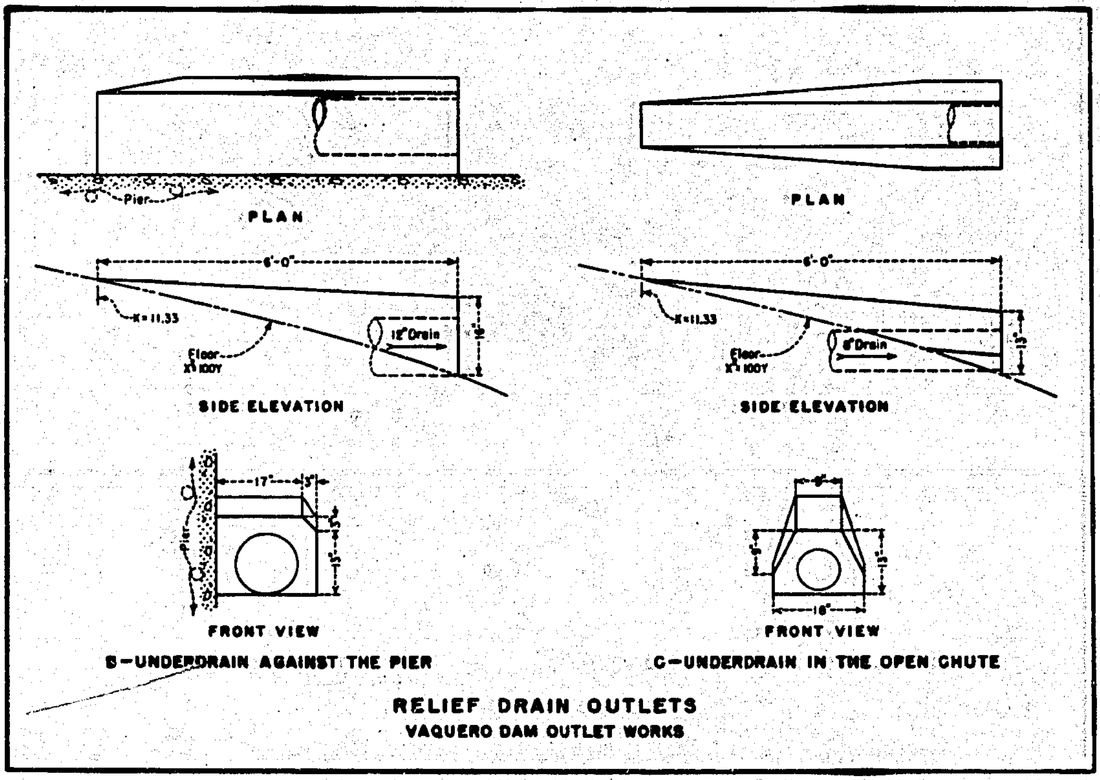
MODEL SCALE - 1:36



CARLSBAD PROJECT – NEW MEXICO
ALAMOGORDO DAM ENLARGEMENT
SPILLWAY MODIFICATIONS
PROFILES AND PRESSURES
RECOMMENDED DESIGN
MODEL SCALE – 1:36



A Looking upstream towards the underdrain outlets.



B Details of the underdrain outlets

ALAMOGORDO DAM

Underdrain outlets